"Bericht über die neueren Untersuchungen am Nordlicht," by L. Végard.[2] This is a very complete bibliographic and mathematical discussion of the subject. The height of the aurora has been determined accurately by simultaneously photographing the same aurora from two stations against a common background of stars, and measuring the parallax obtained. The lower limits of the aurora vary from perhaps 85 kilometers to 170 kilometers, with two well-defined maxima, at 100 and 106 kilometers. The tops extend to heights exceeding 300 kilometers. The magnetic effects accompanying auroras show that they are owing to moving electrons, and their coming most at times of maximum sunspots shows connection with solar disturbances. The electrified particles make the luminosity. Most of the spectral lines are nitrogen lines, but the most prominent one, the "auroral line" is a greenish line of wave length not fitting any known element. The nearest line is a krypton line, but the other krypton lines are not present. [See abstract immediately following this.]

The aurora seems to be caused by electrified atoms discharged from an active area on the sun, which atoms are in part intercepted by the earth's magnetic field and guided toward the magnetic poles. As the particles follow the lines of force in the earth's magnetic field, the visible auroral streamers, which are produced by their action on the atmosphere, are practically straight lines, and therefore produce the coronal or ribbed-dome effect observed whenever an auroral arch with streamers passes through the observer's magnetic zenith.[3] The dark hole (frequently observed at the center of the corona) is the perspective effect produced on looking along the streamer lines.

The electrons have a penetrating power which can carry them through the atmosphere down only to an altitude at which the atmosphere reaches a certain density. Since the particles that form the usual aurora seem to have about equal penetrating power, the under limit is sharply defined and at about the same altitude.

When the aurora reaches a certain degree of intensity, electrical discharges take place, and first where the resistance is least, namely, in the strongly ionized air at its lower limits. The breakdown thence spreads rapidly upwards giving the impression of a rapidly upward moving wave of light.[4]

The variations in the intensity of the aurora probably depend on the varying abundance of arriving particles from the sun, as well as upon the position of the bright spots relative to the observer.—*C. F. B.*

## GENERAL AURORAL ILLUMINATION OF THE SKY AND THE WAVE-LENGTH OF THE CHIEF AURORA LINE.

By V. M. SLIPHER.

[Reprinted from Science Abstracts, sec. A, Sept. 30, 1919, §1165. Abstracted from Astrophys. Jour. 49: 266–275, May, 1919.]

During the past three and one-half years about a hundred spectrograms have been made at the Lowell Observatory of the night sky, and every one of these has recorded the chief aurora line. The spectrograph, therefore, gives direct evidence of the existence of permanent auroral illumination of the sky. The close dependence of displays of aurora upon sun-spot activity suggests that there are variations in the intensity of this general illumination due to the aurora. A preliminary determination of the wave length of the aurora line indicated a longer wavelength than the commonly accepted value λ5571. Further measurements on plates obtained with a higher-dispersion spectrograph gave a mean value for the wave length of λ5578.05. The plates showed clearly that the line falls well to the red side of the strong solar line λ5573.075, and so the value λ5571 must be considerably in error. Stark [Abs. 745 (1918)] has put forward the view that the origin of the chief aurora line is probably the nitrogen pair λλ5560, 5565, but the new value obtained for the wave-length renders this view quite inadmissible.—*A. W.*

[2] Jahrbuch der Radioaktivität und Electronik, 1917, vol. 14, pp. 383–465, 7 figs., 5 tables.
[3] Cf. *Science*, May 14, 1920, N. S. vol. 51, p. 485.
[4] See the more detailed discussion by S. Chapman, "Electrical phenomena in the upper atmosphere;" reprinted in *Sci. Amer. Suppl.*, Sept. 27, and Nov. 29, 1919, pp. 198, and 323; abstracts in *Nature* (London), June 19, 1919, p. 311, and MONTHLY WEATHER REVIEW, Dec., 1919, 47: 879.

## AURORA OF MARCH 4–5, 1920.

[Reprinted from Nature (London), May 13, 1920, p. 337.]

A short article in our issue of March 11, page 56, describing a magnetic disturbance which occurred on March 4–5, mentioned that aurora had been observed at Aberdeen on March 4, but considerably earlier than the commencement of the disturbance, and so presumably not directly connected with it. This seems to have been the only observation of aurora in this country on either March 4 or 5. A letter, however, which we have received from Prof. A. S. Eve, of Montreal, mentions a brilliant aurora as having been observed there between 1 a. m. and 2 a. m. G. M. T. on March 5, and so synchronous with the magnetic storm. Commencing with isolated patches, the aurora appeared for a short time in the form of an arc and ended in a curtain display. This incident leads Prof. Eve to inquire whether there is in existence "an organization for recording, with accurate timing, auroras in both northern and southern hemispheres, and, if so, where can the records be obtained?" So far as we are aware, no such records exist. The question seems to merit the consideration of the recently instituted Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union.

## AURORAS OF 1919 IN THE UNITED STATES.

By HERBERT LYMAN.

[Weather Bureau, Washington, Aug. 31, 1920.]

The following tables of auroras observed in the United States during the year 1919 are based on two sources of data. First, the original monthly meteorological reports of all regular Weather Bureau stations; second, the published "Climatological Data," compiled each month by the several section centers under the supervision of the Climatological Division of the Bureau. The section reports are not, however, all uniform in the matter of listing "Miscellaneous meteorological phenomena" (under which auroras are classed) so that the tables here presented are not all-inclusive. But while there were a few instances where no record was kept of auroral displays, in the main the tables below are reasonably accurate.

Upon examining table 1, one is rather surprised to note the large number of days on which auroras were seen. Thus for the entire year there were 171 auroral displays reported—an average of one aurora to every

TABLE 1.—*Number of States*[1] *in which auroras were reported as observed on any given date in 1919.*

| 1919. | Jan. | Feb. | Mar. | Apr. | May. | June | July. | Aug. | Sept. | Oct. | Nov. | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 4 | 1 | ..... | 1 | 1 | 11 | ..... | ..... | ..... |
| 2 | 1 | ..... | 1 | ..... | 10 | 2 | ..... | 2 | 2 | 5 | 1 | ..... | ..... |
| 3 | 2 | ..... | ..... | ..... | 6 | ..... | ..... | ..... | ..... | 2 | 1 | ..... | ..... |
| 4 | 4 | 1 | ..... | ..... | 2 | 2 | ..... | 1 | ..... | 2 | ..... | ..... | ..... |
| 5 | 2 | ..... | 1 | ..... | 4 | ..... | ..... | ..... | ..... | ..... | 1 | ..... | ..... |
| 6 | ..... | 1 | 2 | 2 | 1 | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... |
| 7 | ..... | ..... | 1 | ..... | ..... | ..... | ..... | 1 | ..... | 2 | ..... | ..... | ..... |
| 8 | 1 | ..... | 1 | ..... | 1 | ..... | ..... | ..... | 1 | 1 | ..... | ..... | ..... |
| 9 | 1 | ..... | ..... | 2 | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... |
| 0 | 1 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | 1 | 1 | ..... | ..... |
| 11 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 8 | ..... | ..... | 1 | ..... | ..... |
| 12 | ..... | ..... | 1 | ..... | 1 | 1 | ..... | 1 | ..... | ..... | 1 | ..... | ..... |
| 13 | 1 | 3 | 1 | ..... | ..... | ..... | ..... | ..... | ..... | 1 | ..... | ..... | ..... |
| 14 | ..... | ..... | ..... | ..... | 1 | ..... | ..... | 1 | ..... | ..... | ..... | 1 | ..... |
| 15 | ..... | ..... | 1 | ..... | ..... | ..... | ..... | ..... | 5 | 3 | 1 | 1 | ..... |
| 16 | ..... | 1 | 2 | 1 | 2 | ..... | ..... | ..... | 1 | 1 | 3 | ..... | ..... |
| 17 | 1 | ..... | 1 | ..... | 1 | ..... | ..... | 1 | 3 | 5 | 2 | ..... | ..... |
| 18 | ..... | ..... | ..... | 3 | 1 | ..... | ..... | 2 | 7 | 1 | ..... | 1 | ..... |
| 19 | ..... | 1 | 3 | 3 | 1 | ..... | 1 | 1 | 8 | ..... | 1 | 1 | ..... |
| 10 | ..... | 4 | 6 | 2 | 2 | ..... | ..... | 1 | 5 | ..... | 1 | 1 | ..... |
| 21 | ..... | 4 | 7 | 4 | 1 | ..... | ..... | 1 | 2 | ..... | 1 | ..... | ..... |
| 22 | 1 | 4 | ..... | 4 | 1 | 2 | ..... | ..... | 2 | 5 | ..... | ..... | ..... |
| 23 | ..... | 1 | 1 | 1 | ..... | ..... | ..... | 1 | 7 | 6 | 2 | ..... | ..... |
| 24 | ..... | ..... | 1 | 1 | 1 | 1 | ..... | 1 | 10 | 1 | ..... | ..... | ..... |
| 25 | ..... | ..... | 2 | 1 | 1 | 2 | ..... | 1 | 5 | ..... | ..... | ..... | ..... |
| 26 | ..... | 4 | 2 | ..... | 1 | ..... | ..... | 1 | 3 | 2 | ..... | ..... | ..... |
| 27 | ..... | 8 | 3 | 1 | ..... | 1 | ..... | 1 | 1 | 1 | ..... | ..... | ..... |
| 28 | 2 | 7 | 2 | ..... | ..... | 1 | ..... | 1 | ..... | 1 | ..... | ..... | ..... |
| 29 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1 | 3 | 1 | 1 | ..... |
| 20 | 1 | ..... | 1 | ..... | ..... | ..... | ..... | ..... | 1 | 1 | ..... | ..... | ..... |
| 31 | 3 | ..... | ..... | ..... | 1 | ..... | ..... | ..... | ..... | 2 | ..... | ..... | ..... |
| Number of days with auroras | 14 | 13 | 21 | 13 | 20 | 9 | 1 | 19 | 20 | 21 | 14 | 6 | 171 |

[1] For the purposes of this table, the District of Columbia is regarded as a State.

2.1 days throughout the year, taking, of course, the country over. In point of seasonal distribution September seems to have been the most favored month, while July was the least.

Table 2 is designed to give a further idea of the seasonal extent of the auroras observed.

Thus no less than 28 such displays were seen in at least four States at one time, while three displays were witnessed in 10 States simultaneously.

Table 2 also shows the number of days on which auroras were seen. In this connection it is interesting to note the distribution (in point of time) of the auroral displays. The first quarter of the year had a total of 48, the second quarter, 42, the third quarter, 40, and the last quarter, 41. March and October had the largest number of displays—21 each. July had the least—only one.

TABLE 2.—*Number of auroras in 1919, arranged by State groups*

| Number of States | 4 | 6 | 8 | 10 |
|---|---|---|---|---|
| Number of auroras | 28 | 13 | 6 | 3 |

It is not practicable to go into any details of these auroras here, but any one wishing to study accounts of of the more prominent ones may apply to the Weather Bureau library for information.

## A SIMPLE EQUATION OF GENERAL APPLICATION FOR THE NORMAL TEMPERATURE IN TERMS OF THE TIME OF DAY AND THE DAY OF THE YEAR.

By FRANK L. WEST, Ph. D.,[1] Physicist, Utah Agricultural Experiment Station.

(Logan, Utah, July 16, 1920.)

SYNOPSIS.

The following empirical equation

$$T=\frac{Ma}{2}+\text{Va}\cos t+\frac{My}{2}\cos\theta$$

represents the normal temperature as a function of the time for the United States except for the arid West, where we must add the term $\left(\frac{\text{Vv}}{4}\cos t\cos\theta\right)$. The constants are the mean annual temperature, the range of the annual march, and the range of the daily march, and are obviously easily obtained from the Weather Bureau data for the place desired. The mean error for the arid West was 2.75° F. and it is less for the rest of the United States. The equation simply assumes that the annual and daily march of temperatures are simple cosine functions.

### DISCUSSION.

It is generally known that the air is alternately warmed during the day and cooled at night and also warmed in summer and cooled in winter. The normal temperature then is a periodic function of the time with a twenty-four hour and an annual period. The writer[2] obtained an empirical equation for these changes with the aid of the Fourier analysis and called attention to the fact that these series, made up of cosine terms, converged so rapidly that the omission of all of the terms except the first two had only a slight effect on the result. Professor Marvin[3] also found that in some regions the annual march of temperature is very approximately represented by a simple cosine curve. Its equation would therefore be

$$Md=Ma+\frac{Va}{2}\cos t \qquad (1)$$

where *Ma* represents the mean annual temperature;
*Md* represents the mean daily temperature for the day *t*;
*Va* represents the annual range in temperature or the difference in the mean daily temperatures of the hottest and coldest day of the year, and
*t* represents the time of the year, zero of time being on the hottest day of the year or at the maximum of the curve.

[1] The writer received helpful suggestions from Dr. Willard Gardner, Associate Physicist, Utah Agricultural Experiment Station.

[2] West, Frank L., Edlefsen, N. E., and Ewing, Scott—"Determination of the Normal Temperature by Means of the Equation of the Seasonal Temperature Variation and of a Modified Thermograph Record." (*In* Physical Review, Vol. 14, No. 3 (1919). Also *in* Jour. Agr. Rsch., Vol. 18, No. 10 (Feb., 1920). *Abstract in* MONTHLY WEATHER REVIEW, Dec., 1919, 47:877.

[3] "Marvin, C. F.—Are Irregularities in the Annual March of Temperature Persistent?" (*In* MONTHLY WEATHER REVIEW, Vol. 47, No. 8, p. 544 (1919).
This paper indicates that for a section of the northeastern United States represented by New England and the States of New York, Eastern Ohio, Pennsylvania, Maryland, and part of Virginia, the annual curve of temperature is well represented by a single cosine curve. Elsewhere in the United States two terms are in general required with an amplitude of the second term of 1 to 2 or more degrees. In the arid southwest later studies show three terms are necessary for cousistent accuracy.
The literature on the subject is best reviewed in the two following articles: Pernter, J. M.—"Present Status of Our Knowledge of the Causes of the Diurnal Changes in Temperature, Pressure, and Wind." (*In* MONTHLY WEATHER REVIEW, Vol. 42, No. 12, pp. 655-665 (1914).
Talman, C. Fitzhugh—"Literature concerning Supposed Irregularities in the Annual March of Temperature." (*In* MONTHLY WEATHER REVIEW, Vol. 47, No. 8, pp. 555-565 (1919).